

2023 IEEE PES ISGT-Europe

October 23rd-26th, 2023, Grenoble, France

Weather-Based Quasi Dynamic Thermal Ratings for Power Transformers

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Mines Paris - PERSEE

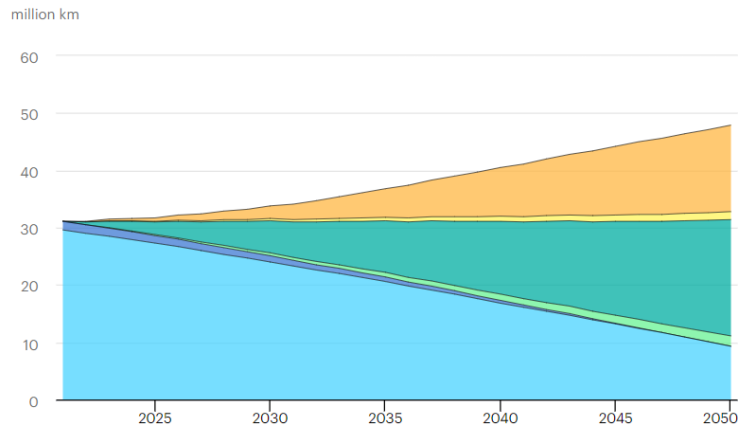
Paper N°: A8875SM



CONTEXT

Grid length development in advanced economies in the Announced Pledges Scenario, 2021-2050


Open 

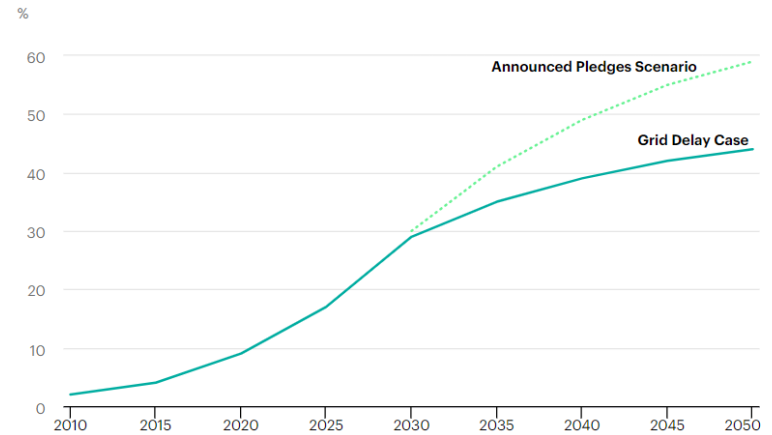


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- Existing Dx
- Existing Tx
- Replaced Tx
- Replaced Dx
- Additional Tx
- Additional Dx

Share of solar PV and wind in power generation worldwide in the Grid Delay Case and the Announced Pledges Scenario, 2010-2050

Open 



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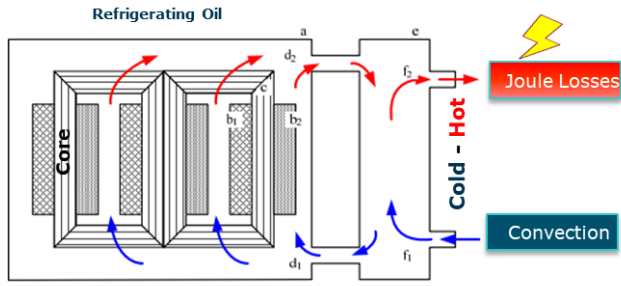
- Announced Pledges Scenario
- Grid Delay Case

[1a]

Outline

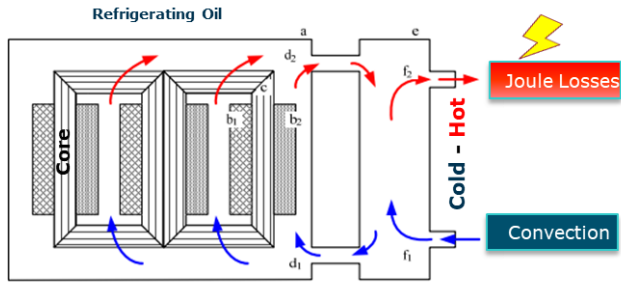
- Introduction and Context
- Results
- Methodology
- Conclusion

THERMAL RATINGS



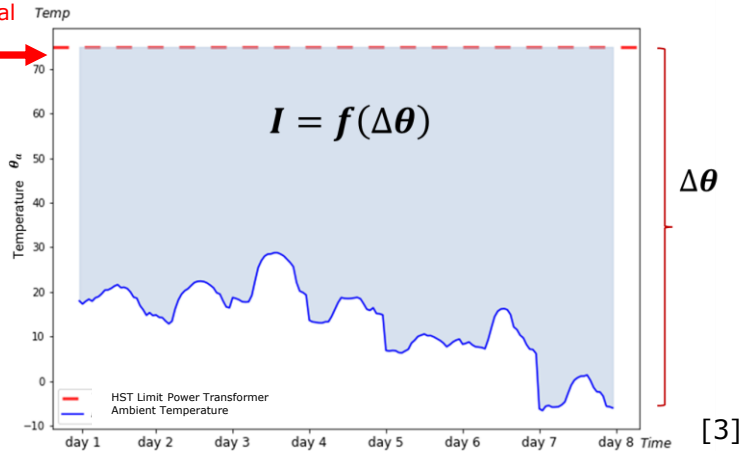
- [1]
- | | | | |
|-------------------------------|-----------------------|-------------------------------|---------------------------------|
| a | Oil tank | d ₁ d ₂ | Coolant oil flow (cold, hot) |
| b ₁ b ₂ | Windings (+-) | e | Heat exchanger |
| c | Ferromagnetic circuit | f ₁ f ₂ | Refrigerating fluid (cold, hot) |

THERMAL RATINGS

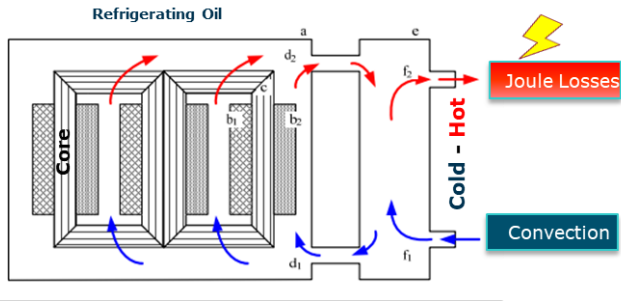


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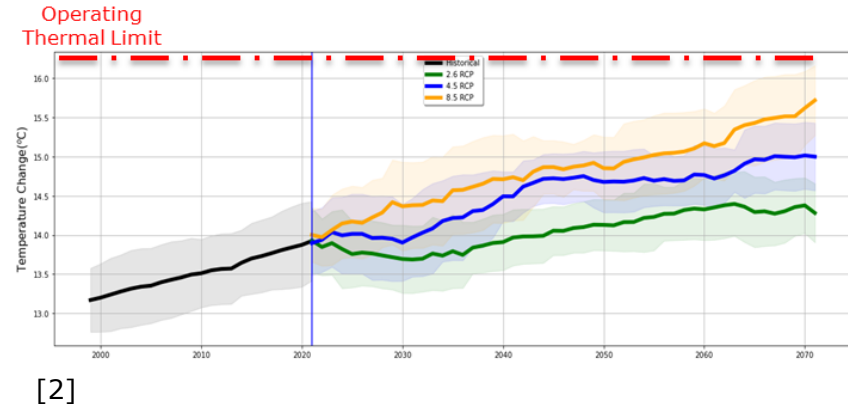
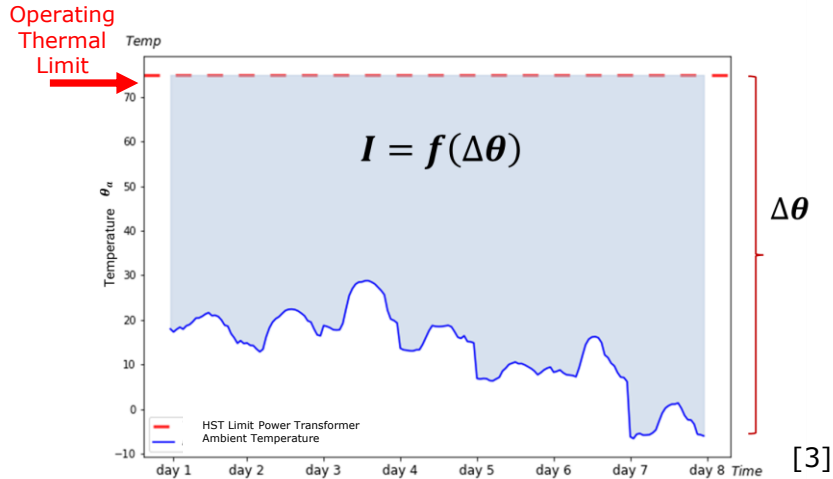
Operating
Thermal
Limit



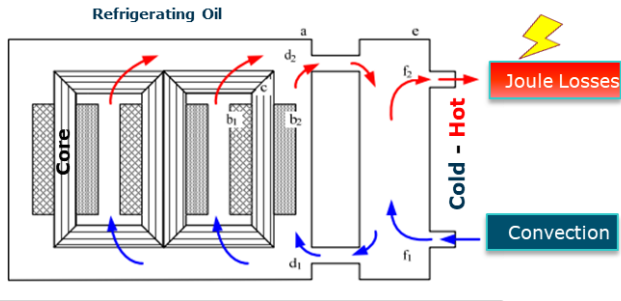
THERMAL RATINGS



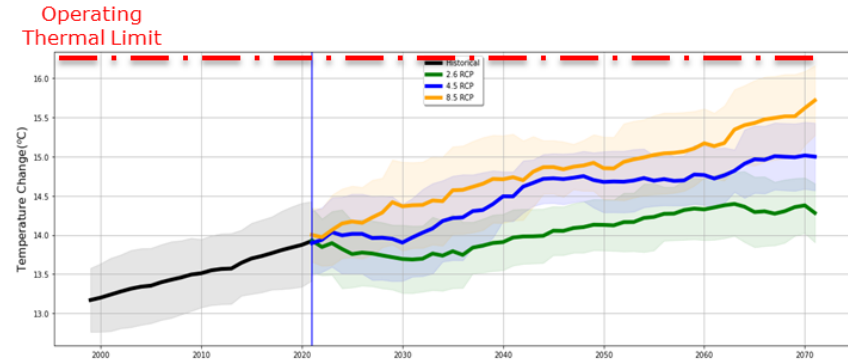
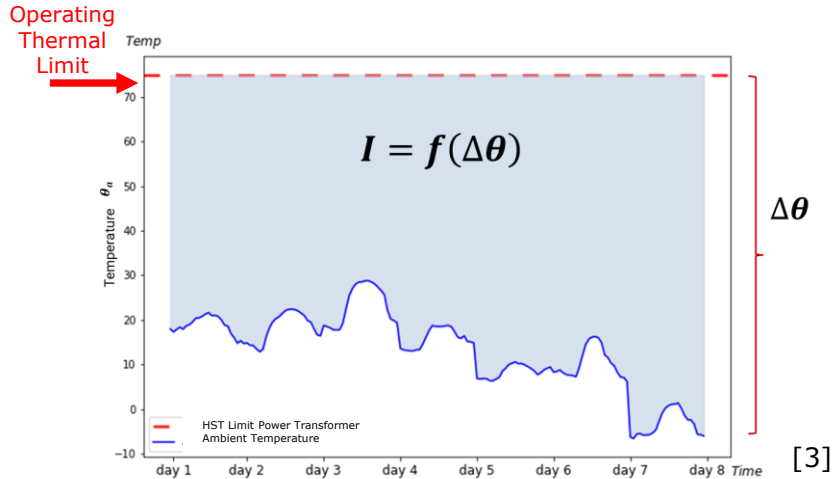
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THERMAL RATINGS



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[2]

What will be the impact of climate change?






How to estimate the impact?

Outline

- Introduction and Context
- **Results**
- Methodology
- Conclusion

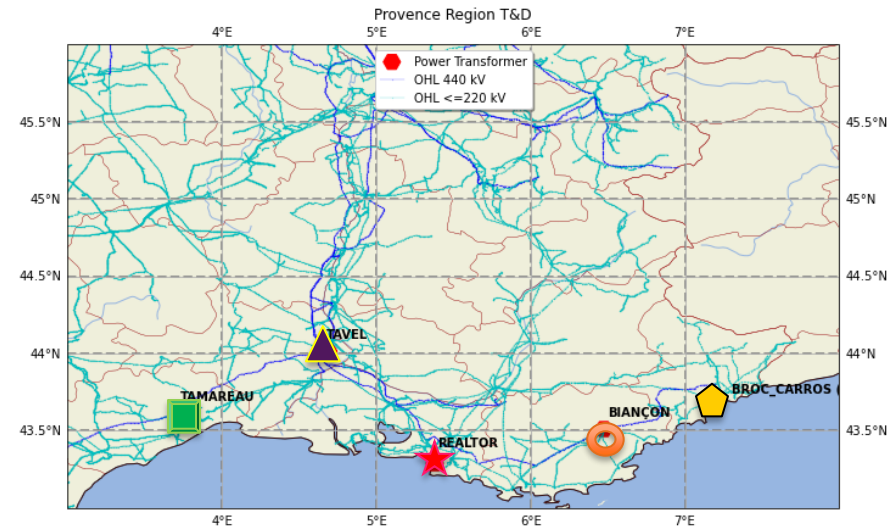
RESULTS

TABLE III: Average, minimum and maximum qDTR values compared to historical values

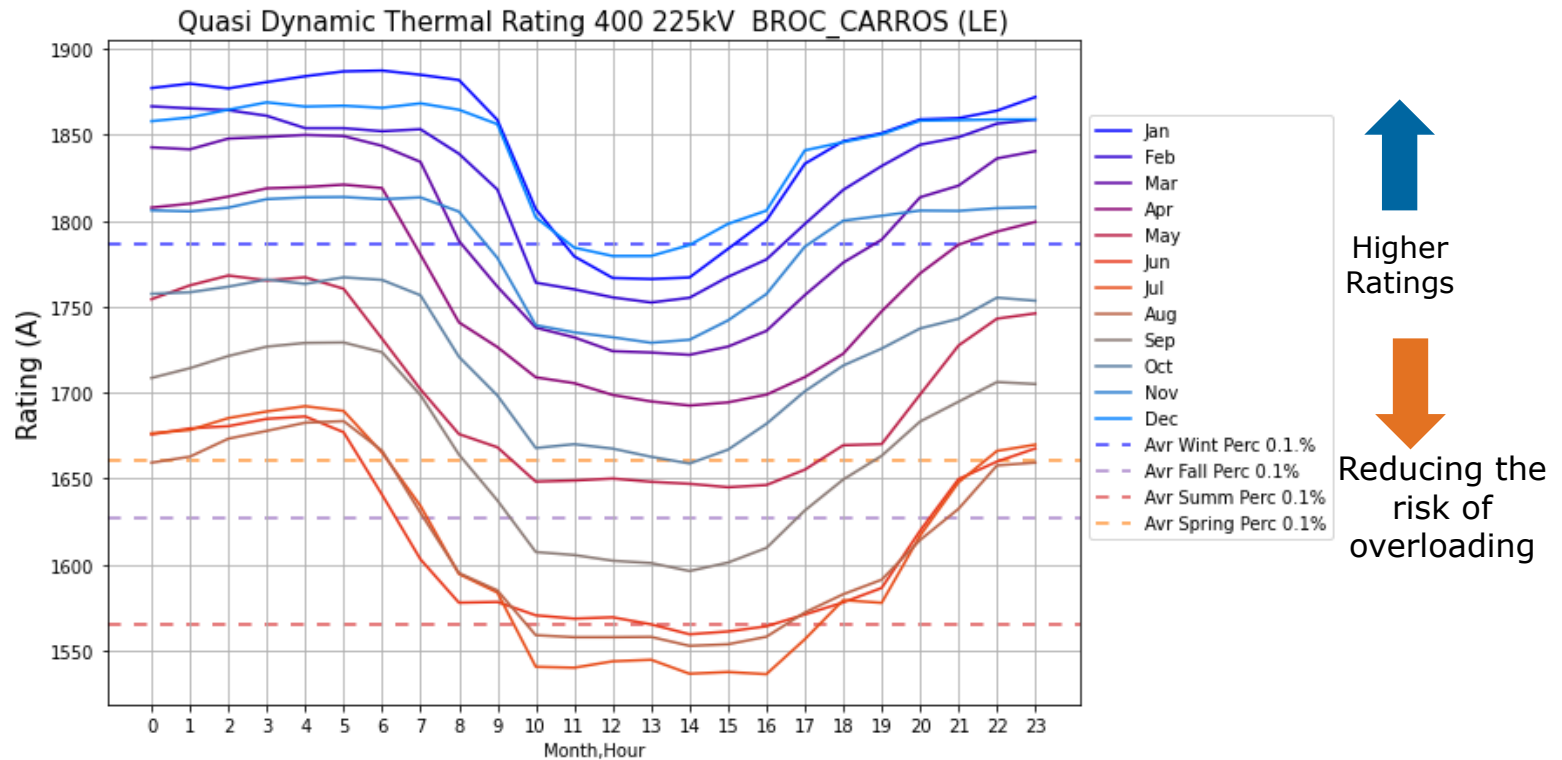
Description	Realtor 	Biaçon 	Broc-Carros 	Tamareu 	Tavel 
Hist Avg (A)	1716	1652	1711	1575	1636
Hist Max (A)	1851	1787	1862	1706	1805
Hist Min (A)	1543	1455	1519	1363	1340
2.6 RCP Avg	-0.3%	-0.2%	-0.2%	-0.3%	-0.4%
2.6 RCP Max	0.18%	0.45%	0.013%	0.6%	0.31%
2.6 RCP Min	0.06%	-0.8%	-1.0%	-2.1%	-0.8%
4.5 RCP Avg	-0.9%	-0.73%	-0.74%	-0.5%	-0.8%
4.5 RCP Max	-0.5%	0.647%	-0.8%	0.28%	-0.08%
4.5 RCP Min	-0.7%	-1.379%	-0.5%	-1.69%	-0.68%
8.5 RCP Avg	-1.67%	-1.69%	-1.62%	-1.01%	-2.07%
8.5 RCP Max	-1.03%	0.16%	-1.41%	-0.23%	-0.84%
8.5 RCP Min	-3.72%	-3.44%	-3.86%	-2.21%	-1.87%

Answer # 1 – Climate change could reduce average rating up to 2%

Map Of Provence Transmission Network With A Location Of PT



Results Broc-Carros with an exceedance probability of 0.1%

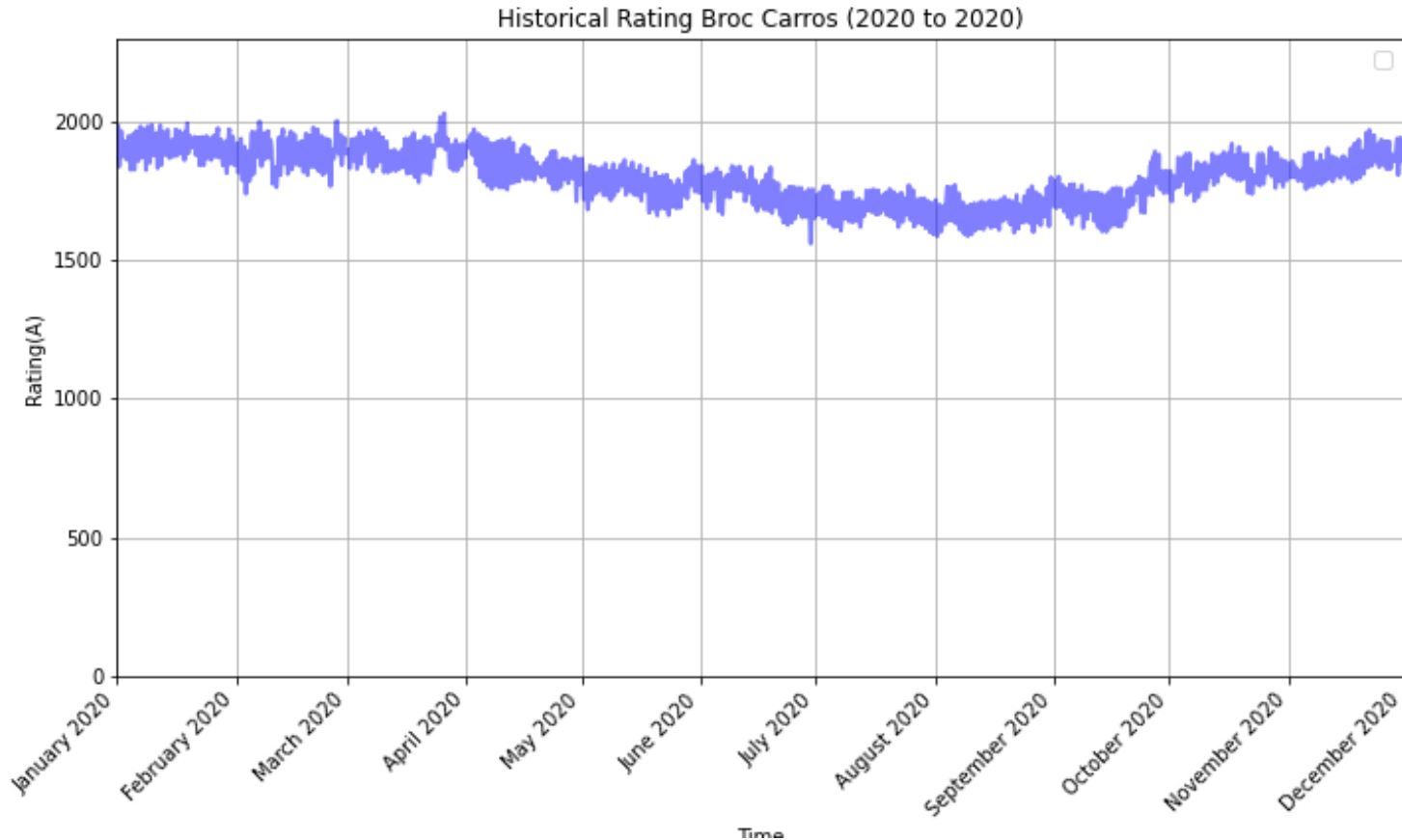


Answer # 2 – The qDTRs methodology introduced an average uplift in the region of 7.7%

Outline

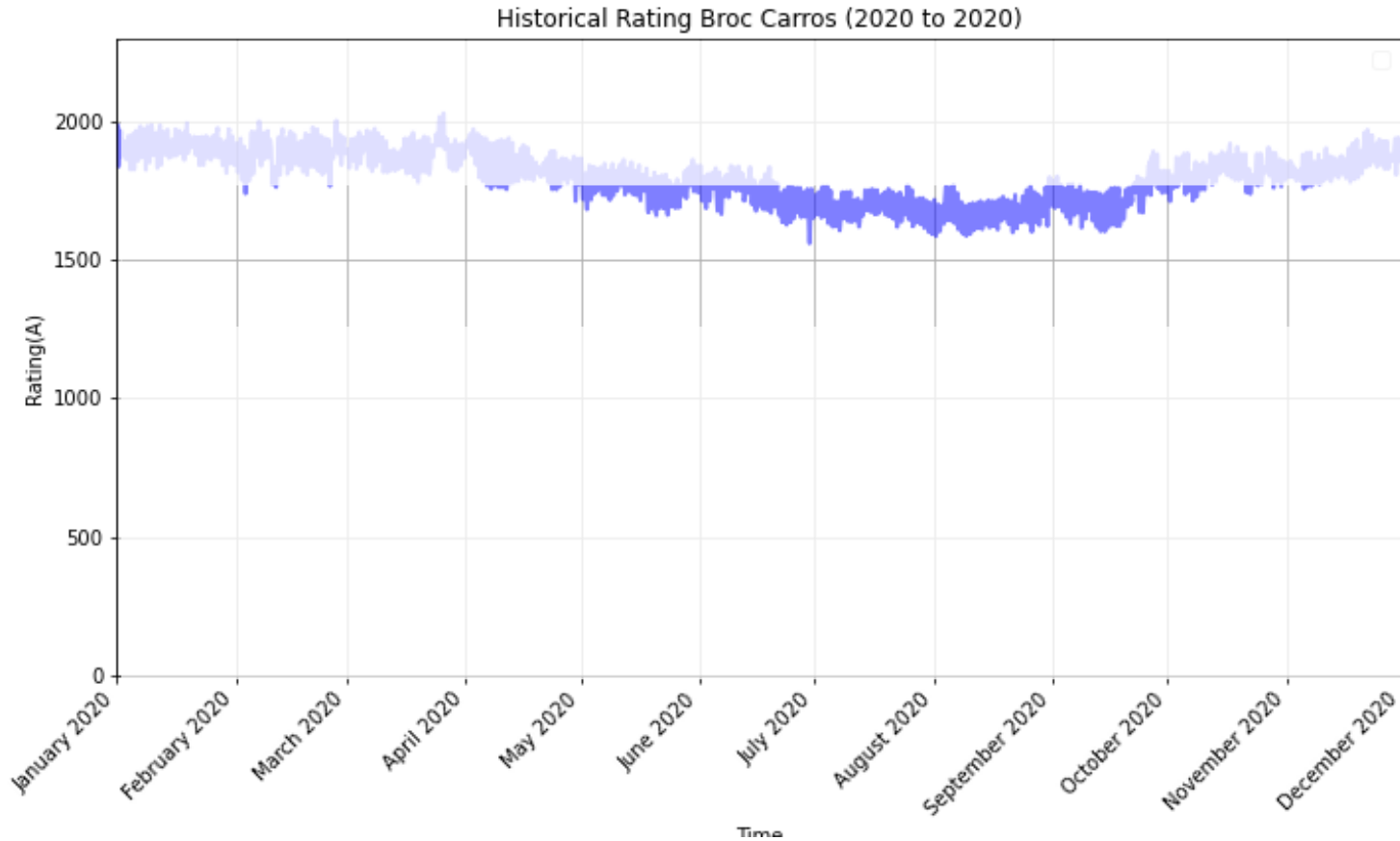
- Introduction and Context
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Dynamic Thermal Rating: approaches



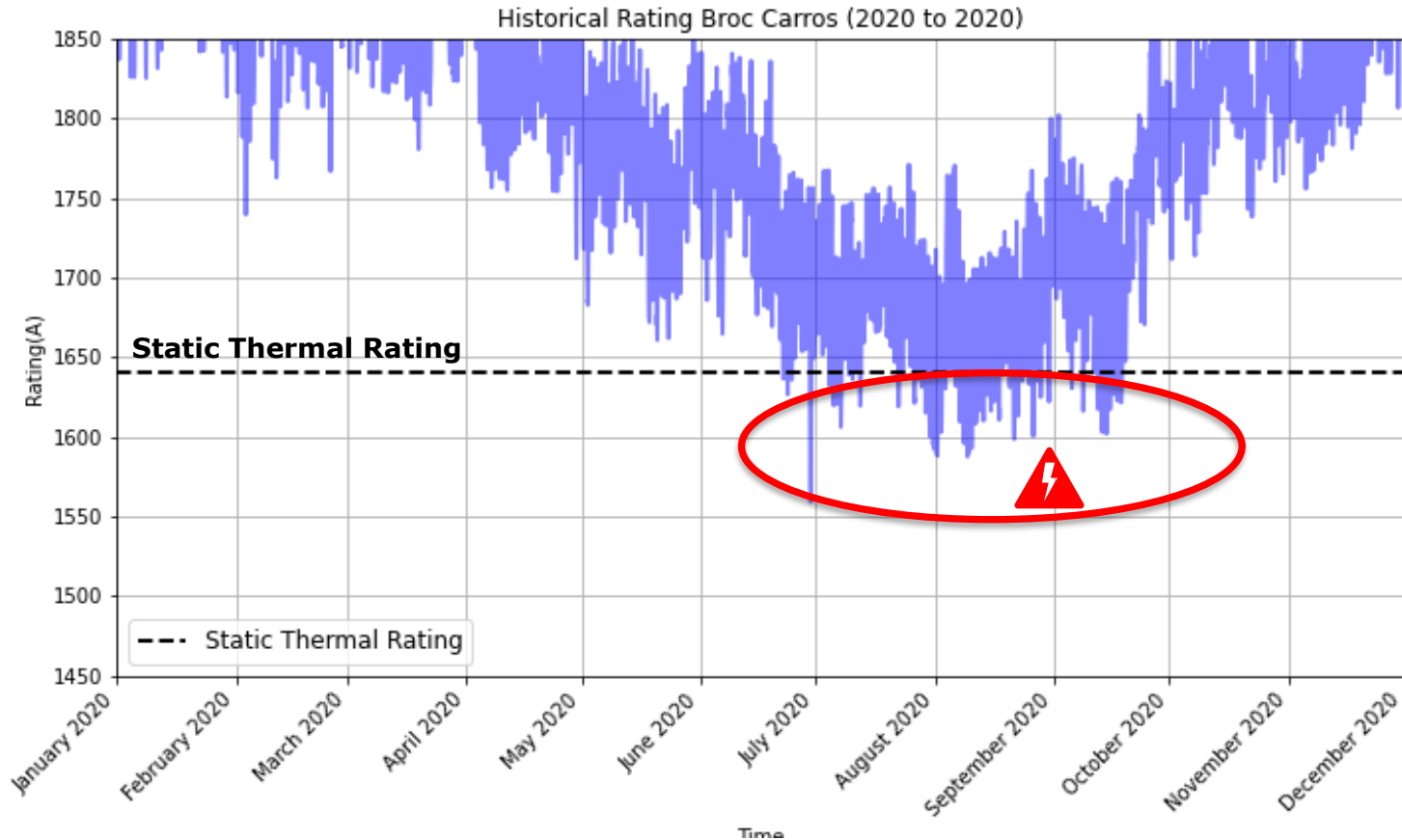
$$I_{qDTR}(\theta_a) \forall t \in [1, 2 \dots 24]$$

Dynamic Thermal Rating: approaches



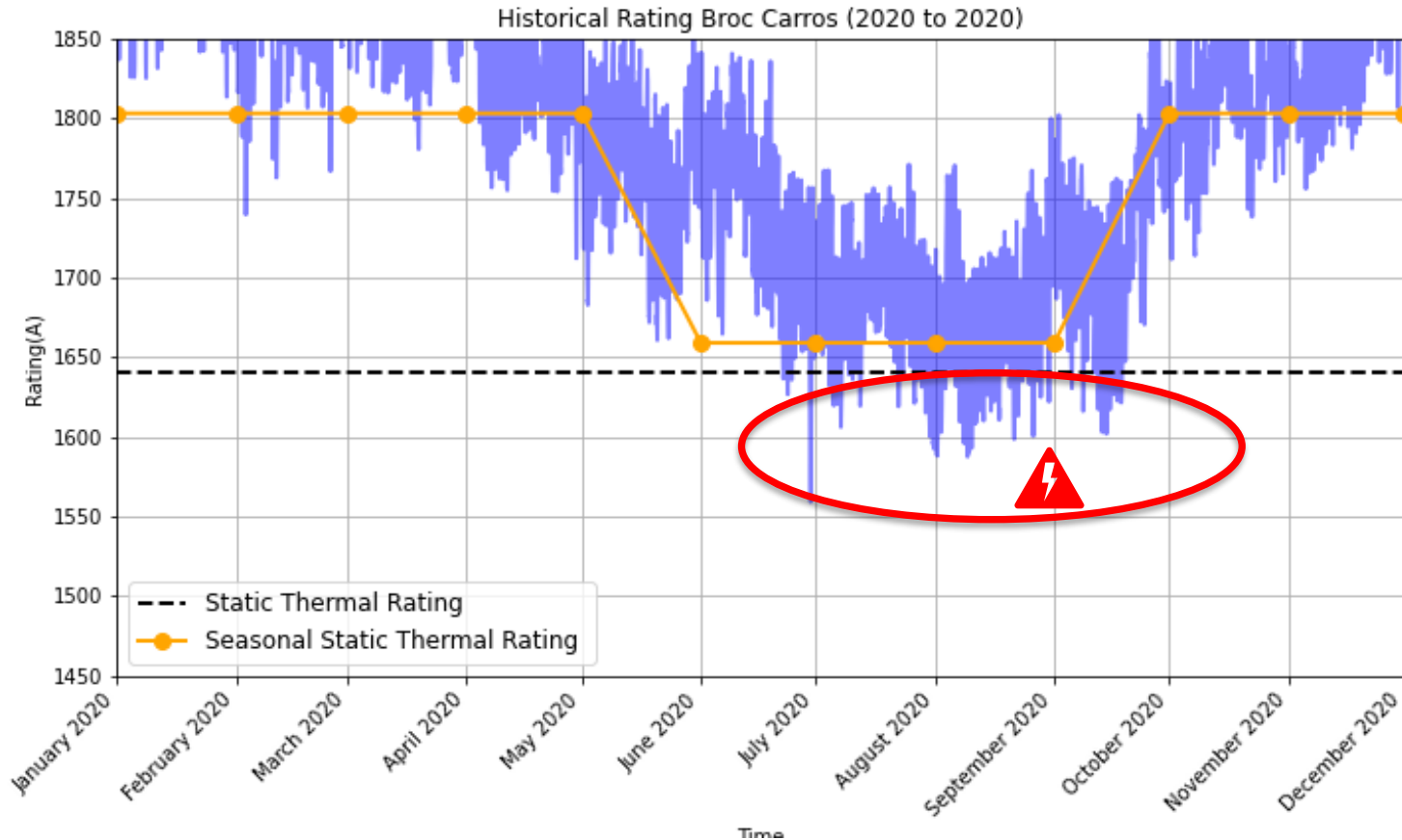
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Dynamic Thermal Rating: approaches



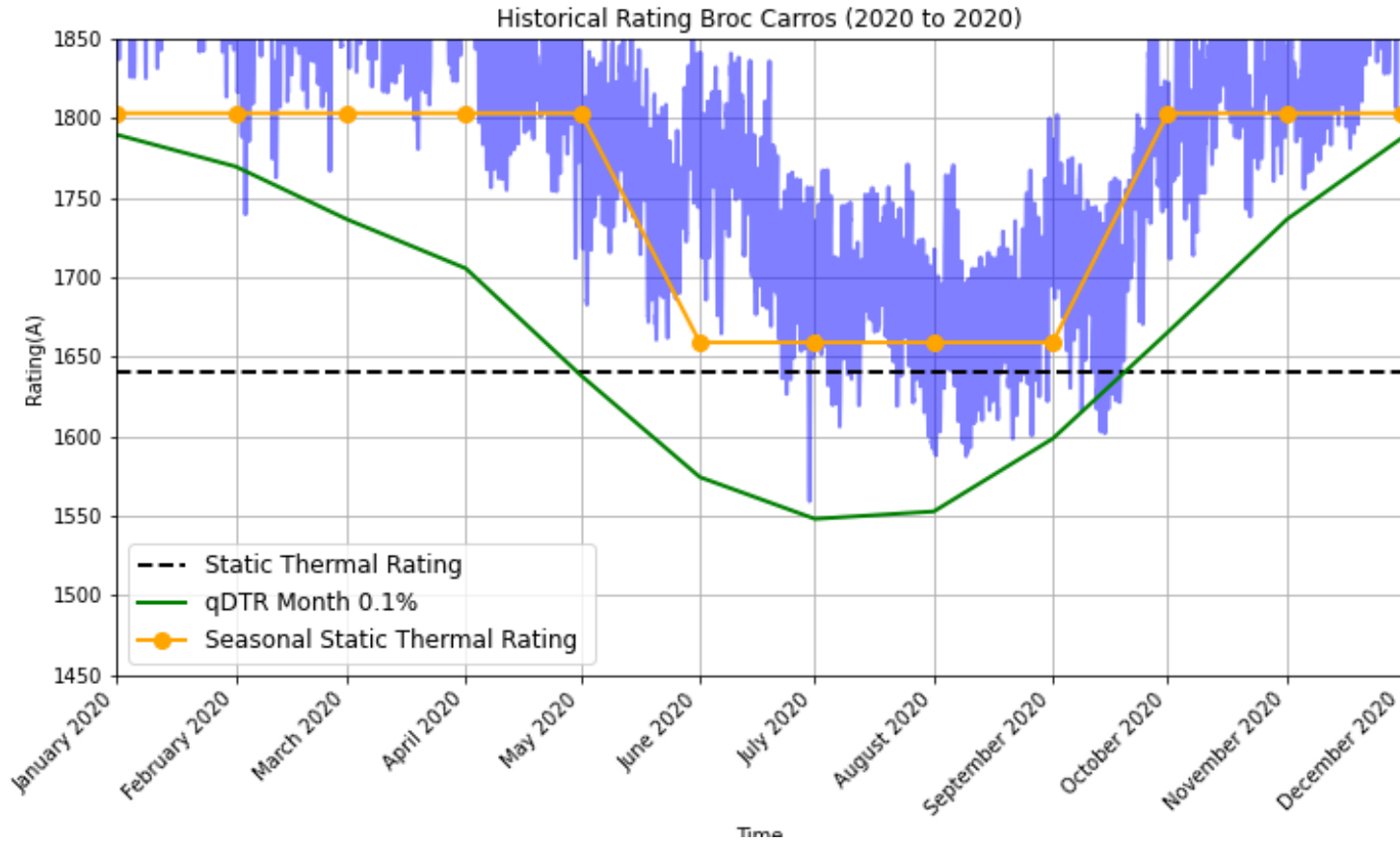
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Dynamic Thermal Rating: approaches



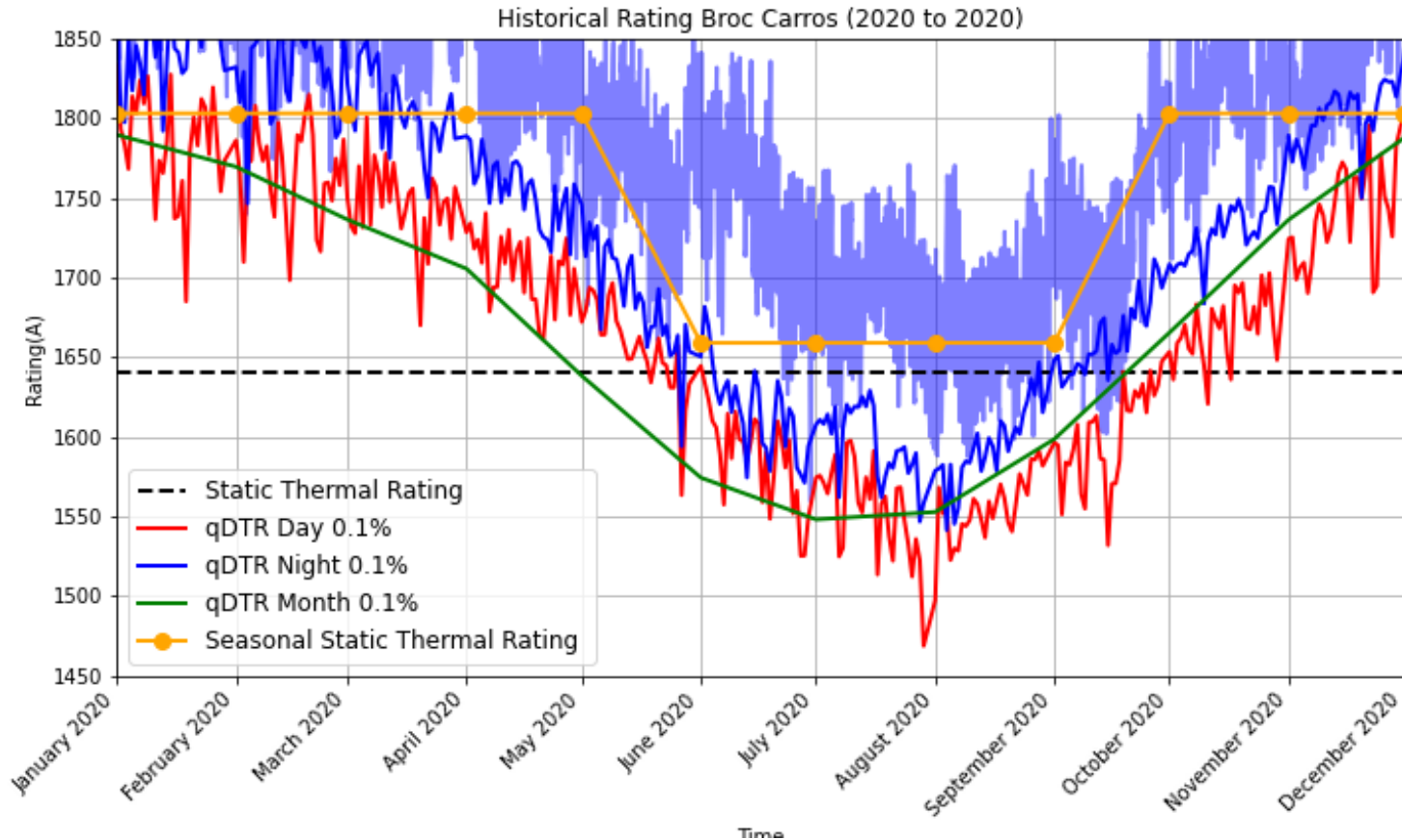
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Dynamic Thermal Rating: approaches



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Dynamic Thermal Rating: approaches

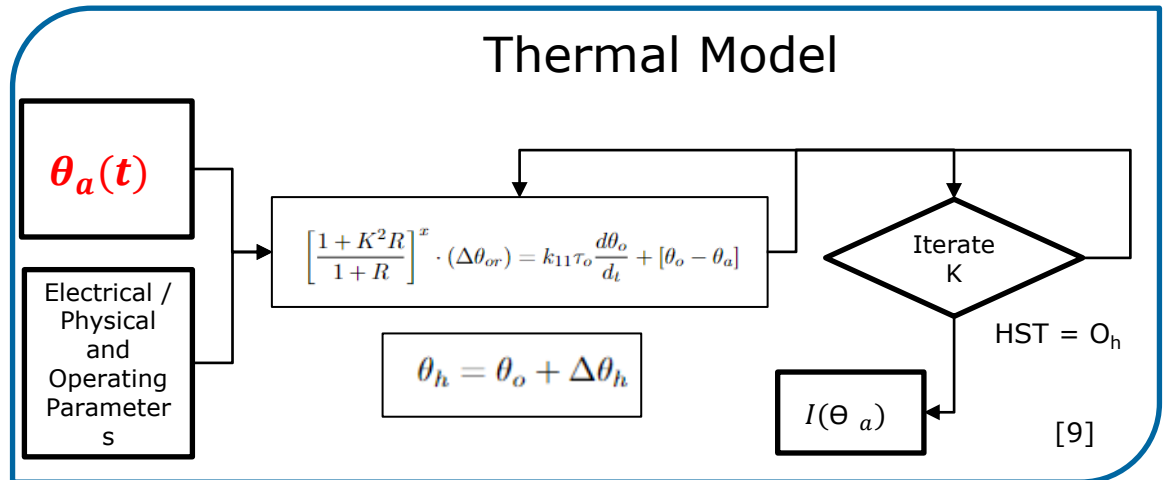
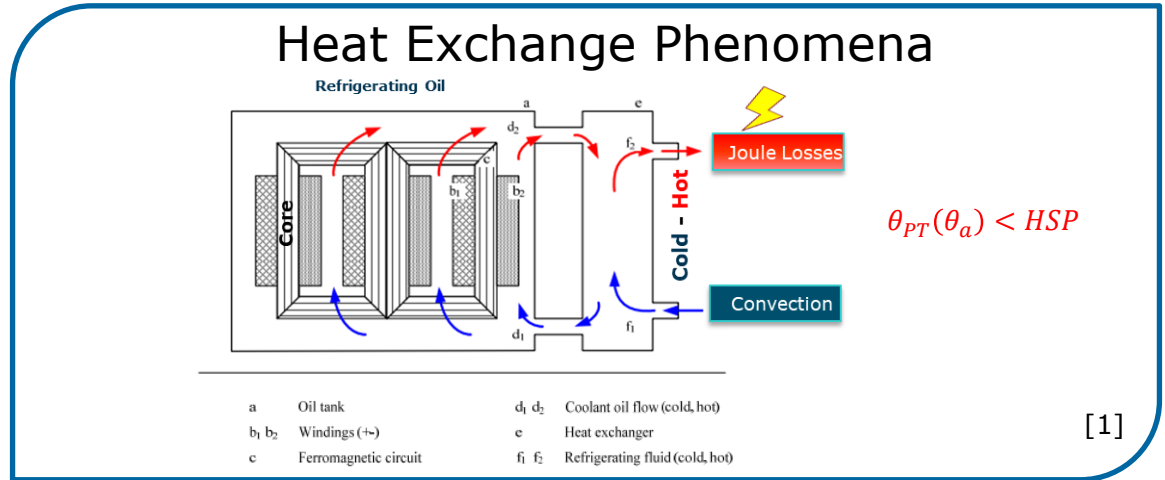


$$I_{qDTR}(\theta_a) \forall t \in [1, 2 \dots 24]$$

THERMAL MODELS PT



EEP ELECTRICAL EQUIPMENT PORTAL



DATA

TABLE I: Thermal Characteristic listed in IEC 60076-7 used in PT model equations

Parameter, Units	Symbol or Reference	Value
Oil exponent	x	0.8
Winding Exponent	y	1.3
Loss Ratio	R	6
Hot-Spot Temperature (oC)	θ_h	98
Hot-Spot to top-oil (oC)	$\Delta\theta_{hr}$	26
Tap-Oil Temperature Raise (oC)	$\Delta\theta_{or}$	52
Constant	K_{21}	2

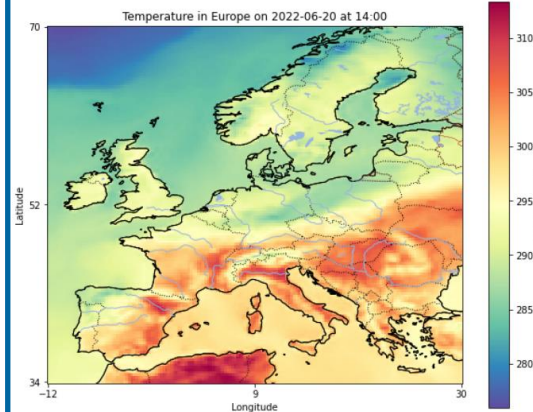
[9]

TABLE II: Power transformer list with parameters for qDTR analysis

Unit	Name	Calculated Power (MVA)	Resistance R(Ω)	Reactance X(Ω)
T_1	Le Broc-Carros	1194	0.1	42.3
T_2	Biaçon	1168	0.24	43.1
T_3	Realtor	1210	0.12	41.7
T_4	Tamareau	1119	0.25	45
T_5	Tavel	1184	0.14	42.6

[6,7]

ERA5 Hourly Data On Single Levels From 1940 To The Present

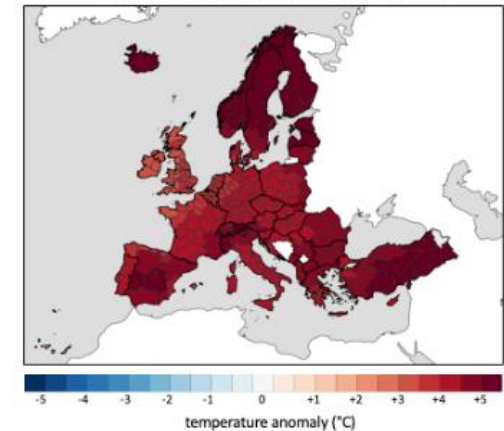


[10]



Climate And Energy Indicators For Europe From 2005 To 2100 Derived From Climate Projections

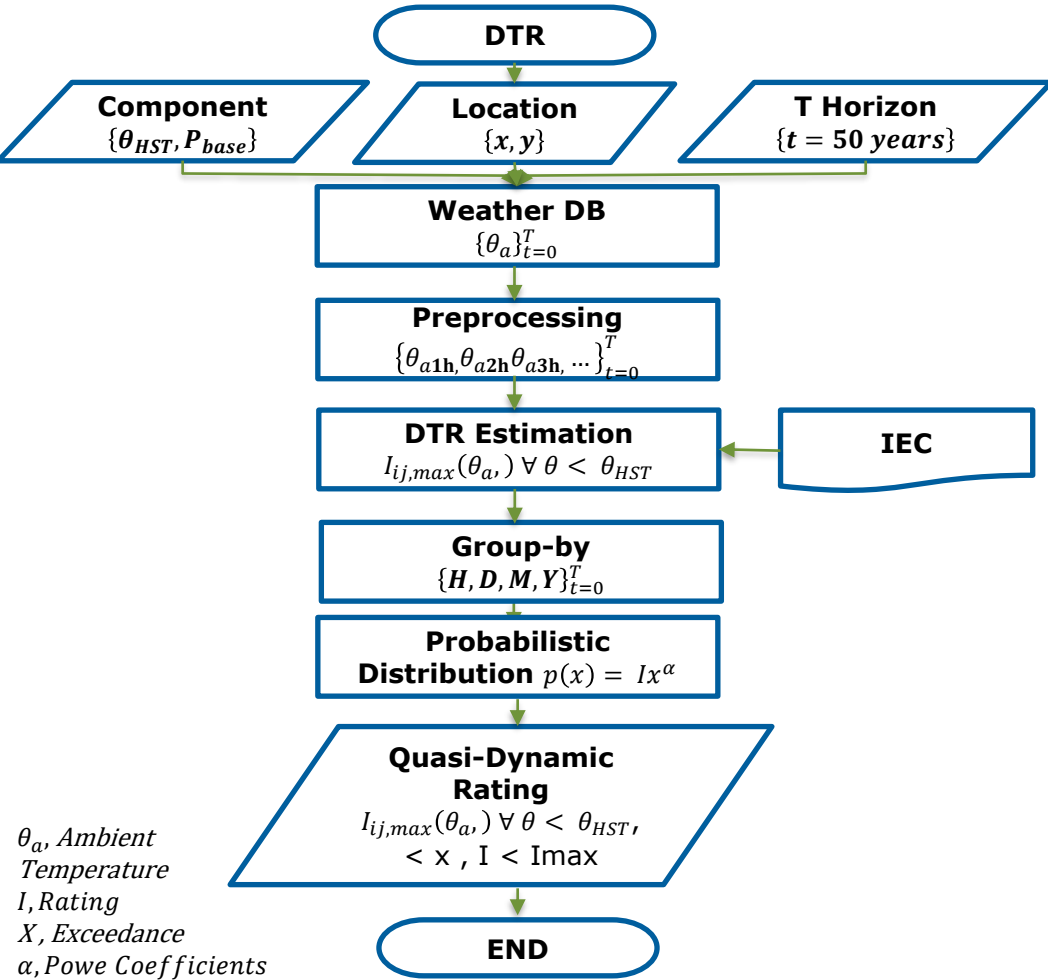
2100 temperature anomaly (RCP 8.5)



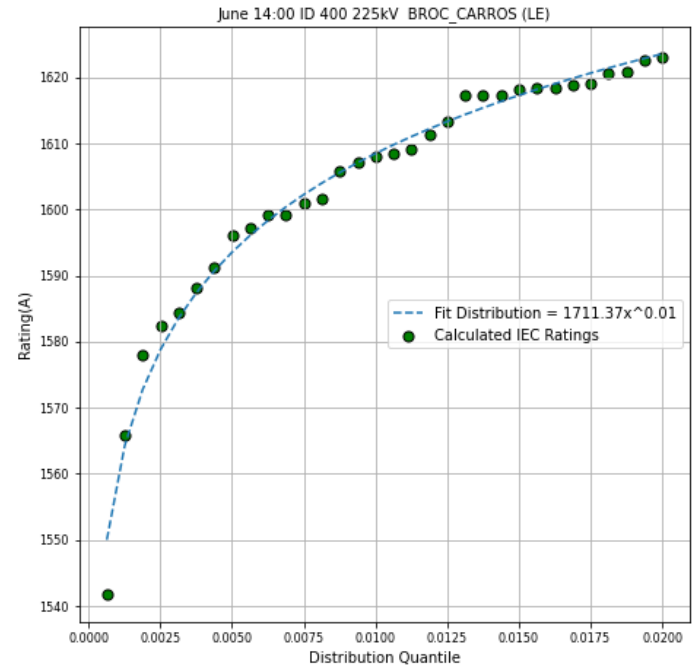
[11]



RESOURCE ESTIMATION : qDTR



Broc-Carros Power law distribution fitting and calculating dots of the lower quantile $p(x) = Ix^\alpha$



[8]

Outline

- Introduction and Context
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CONCLUSIONS

What will be the impact of climate change?

- Climate change could reduce average rating up to 2%
- The qDTRs methodology introduced an average uplift in the region of 7.7%

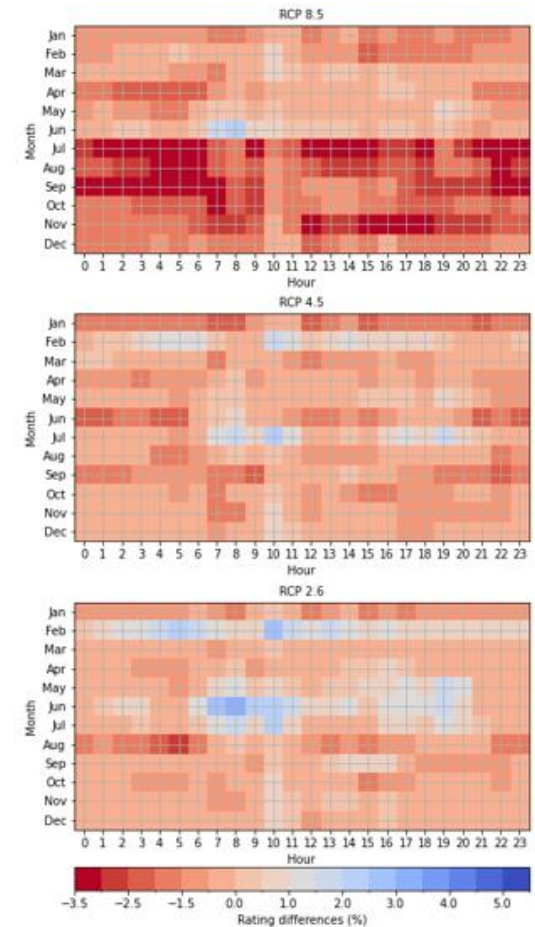
How to estimate the impact?

- qDTRs are calculated hourly/month in this work considering an exceedance probability level set at 0.1%.

Outlook

- Integrate thermal analysis into other components such as Overhead Lines and Underground Cables.
- Implement other meteorological variables such as solar irradiance and wind speed and conduct regional analyses
- Perform an economic analysis of investment and operating costs.

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